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Short-term evolution of edaphic parameters of mountain pastures after temporary night camping of sheep and goats

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Abstract. Pastoral mountain commons in the north of Spain are experiencing acute shrub encroachment and soil degradation. Livestock temporary night camping (TNC) is a traditional tool to concentrate fertility, generate high value grassland patches and ameliorate livestock grazing distribution. In this work we quantify the short-term effects of sheep TNC or goats TNC on soil fertility changes. Soil samples were collected 1 day before and 1 day, 2, 4 and 6 weeks after the establishment of 10 different TNC. Sheep and goat faeces were also collected after each TNC. Faeces and soil parameters measured were : pH, electrical conductivity –EC–, nitrogen, phosphorus and potassium. For faeces parameters, analyses of covariance were performed with time as covariable and livestock species as fixed effect. Each soil parameter was analyzed using mixed linear models, considering as fixed effects the livestock species, the value just before the TNC, and time. In faeces all parameters did not change with time but inter-specific differences were found, except for pH and organic matter. In all soil parameters, except EC, the value before TNC affected later values. Time was only significant for nitrogen (decrease), nitrate and EC (increase) ; no Time x Species interactions were found. Nitrogen in soil was higher for sheep TNC than for goats TNC, while the opposite trend was found for potassium, phospohrus and EC. Results are discussed with relation to the different grazing diets of sheep and goats and the characteristics of these podsolic soils.

Keywords. Cantabria – Faeces – Soil fertility – Grazing.

Evolution à court terme des paramètres édaphiques des alpages après le camping nocturne intensif d'ovins et de caprins

Résumé. *Les pâturages communs de montagne du nord de l'Espagne connaissent un empiétement important des buissons et une dégradation des sols. Le parcage temporaire de nuit pour le bétail (TNC) est un outil traditionnel pour concentrer la fertilité, générer des zones de pelouse de bonne valeur pastorale et améliorer la répartition du pâturage. Dans ce travail, nous quantifions les effets à court terme de TNC ovin ou bien caprin sur les modifications de la fertilité du sol. Des échantillons de sol ont été collectés 1 jour avant et 1 jour, 2, 4 et 6 semaines après la mise en place de 10 différents TNC. Des fèces d'ovins et de caprins ont également été collectées après chaque TNC. Les paramètres mesurée sur les fèces et le sol étaient le pH, la conductivité électrique –EC–, l'azote, le phosphore et le potassium. Pour les matières fécales, des analyses de paramètres de covariance ont été effectuées avec le temps comme covariable et les espèces d'élevage comme effet fixe. Chaque paramètre de sol a été analysé à l'aide de modèles linéaires mixtes, en considérant comme effets fixes l'espèce animale, la valeur juste avant la TNC et la date. Aucun des paramètres des fèces n'a changé avec le temps, mais des différences entre espèces ont pu être mises en évidence, sauf pour le pH et la matière organique. Dans tous les paramètres du sol, sauf pour EC, la valeur avant TNC a affecté les valeurs ultérieures. Le temps n'était significatif que pour l'azote (diminution), les nitrates et EC (augmentation) ; aucune interaction Date x Espèce a été trouvée. L'azote dans le sol était plus élevé pour les TNC ovins que pour les TNC caprins, alors que la tendance inverse a été observée pour le potassium, le phosphore et EC. Les résultats sont discutés en relation avec les différents régimes de pâturage des ovins et des caprins et les caractéristiques de ces sols podsoliques.*

Mots-clés. *Cantabria – Fèces – Fertilité du sol – Pâturage.*

I – Introduction

Livestock grazing systems in the mountain commons of northern Spain have evolved in the last 50 years towards dominance of sucker cows and mares in systems with minimum pastoral management. The acute decrease in small ruminants and the absence of herders and proper land management practices is boosting shrub encroachment by plants, especially gorses and heaths, which also reactivate uncontrolled and undesirable fires and burning regimes (Beaufoy and Ruiz-Mirazo, 2014). Shrub encroachment is linked with soil impoverishment (Montserrat, 1980), so there is an urgent need to promote practices that can revert this trend and create improved pastures to help balance livestock diets and activate sustainable grazing patterns and behaviours.

In mountain areas of Spain, the practice known as "*redileo*" (temporary night camping –TNC–) with sheep was a traditional way to fertilise cheaply and effectively meadows and pastures of commons (Fillat *et al.,* 1984). The "islands" of soil fertility created by this practice may generate grassland patches of high nutritional value (Tocco *et al.,* 2013) and of high resilience against fire.

In this study we evaluate the short-term changes of some edaphic parameters (pH, electrical conductivity –EC–, N, P and K) in patches of mixed herbaceous-shrub moorland subjected to TNC, and relate them to the quality of the faeces excreted by goats and sheep.

II – Materials and methods

1. Study area

The experiment was performed in the north of Spain (ETRS89 43º15´01´´N. 4º6´09´´W; 450 msnm), in a mountainous paddock of 4.3 ha with 17% of the area of improved pasture and the rest of moorland herbaceous-shrub vegetation. In June 2018 two small autochthonous flocks of 25 *carranzana* sheep and 25 *pirenaica* goats were introduced in the paddock and kept inside until October 2018. In the years before the experiment the area was grazed mainly by beef suckler cows at a low grazing pressure. The temporary night camps (TNC) were always set in the moorland part of the paddock, where the most abundant herbaceous species were the grasses *Agrostis curtisii*. *Pseudarrhenatherum longifolium* and *Molinia caerulea*, accompanied by short shrubs mainly of *Ulex gallii* and *Erica mackaiana*.

The soils where the TNC were installed had the following initial characteristics: pH=4.6±0.12(s.d.); electrical conductivity (EC)=0.05±0.01 mS cm^{-1}; carbonates=0.07±0.13%; organic matter (OM)=9.6±2.03%; total nitrogen (N)=0.54±0.07%; C/N ratio=10.3±1.10; P=8.5±2.94 ppm; Ca=356±84.2 ppm; Mg=77.5±28.1 ppm; K=94.0±31.1 ppm; Fe=394±53.8 ppm; Mn=1.6±1.43 ppm; exchangeable acidity=3.1±0.55 cmol kg^{-1}; Al=21±5.2 meq kg^{-1}; CEC=16.0±4.9 cmol kg^{-1}; sand=79.8±3.4%; silt=19.0±3.3% and clay=1.2±0.8%.

2. Experimental design and response variables

From July to October of 2018, 10 successive paired TNC were established. In each of these, the goats and sheep spent the night (average of 11 hours) separately in half of the TNC during 5 consecutive days, with an area of 3 m^2 per animal.

Animal faeces were collected just after the duration of each TNC, dried, sieved to 2mm and analysed for pH (water/faeces ratio 2.5 :1), EC (water/faeces 1 :5), OM (Walkley-Black method), extractable P (Olsen) and total N (Kjeldahl). From the value of N in faeces, total N added to the soil (g m^{-2}) by the animals (faeces and urine) was estimated using the equations provided by Hobbs (2006). Soil composite samples were collected from 3 fixed positions within each sheep/goat separation of each TNC just before and after the duration of the camping, as well as 2, 4 and 6 weeks after. The variables analysed in each soil sample were pH, EC, extractable P, total N, nitrates and available K. The first 5 variables were calculated as in faeces and K was extracted by emission with ammonium acetate at pH7. The nitrate content was measured by means of the Nitrachek test.

3. Statistical analyses

Temporal dynamics and livestock differences in faeces parameters were analysed using a simple analysis of covariance, with time (days) as covariable and livestock species as fixed-effect. In the case of TNC soils, mixed effect linear models were performed to analyse the temporal dynamics and possible livestock species differences of each of the measured parameters after TNC. Initial values of the soil parameters were tested as covariables, livestock species (sheep or goat) as fixed effect, days after TNC as continuous explanatory variable (in linear and quadratic terms) and specific TNC and position (goat or sheep) nested within the TNC as random effects. AIC comparisons between nested maximum likelihood models were used to attain the most parsimonious model.

III – Results and discussion

In faeces none of the variables analysed showed significant effects of time or of the interaction of livestock species with time, reflecting a fairly constant grazing diet along the studied period. pH and OM values were not significantly different for goats and sheep, while the rest of variables (EC, P, N and C/N) differed with the species (Table 1). pH was one unit higher than intensive dairy cows systems (Morgante *et al*., 2009; Luan *et al*., 2016). P and N values were highly correlated (r=0.88) and higher in sheep than in goats. The P-N correlation may be explained by the probable correlation existing for these nutrients in the plants consumed by goats and sheep. The higher values of N and P in sheep than goats were probably caused by their richer diet, as estimated for N in the simulation perfomed (0.021% vs 0.016% ; s.e.d.= 0.0009). The presumably higher dry matter intake of goats due to their higher body mass (mean values of 47 kg for ewes and 59 kg for goats), finally resulted in similar total N excretion (urine + faeces), as is suggested by the obtained simulated values (Hobbs, 2006; last row of Table 1). These simulations also predicted lower digestibility of the diet of goats (0.59) than sheep (0.66; s.e.d=0.012), which also would add for a higher faeces excretion of goats. The C/N ratio was mainly determined by the faeces N content (r=0.90). Their values for sheep were potentially more appropriate as soil organic amendment than those of goats.

Table 1. Mean values for the livestock species of the response variables characterizing the faeces collected in the temporary night camps

Variable	Goats	Sheep	s.e.d	R^2_{adj}	RSE
pH	7.72		0.057		0.26
EC (mS/cm)	0.78	1.32	0.202	0.24	0.45
OM (%)	49.80		0.985		4.41
P (ppm)	593.9	1032.1	171.3	0.23	383
N (%)	1.48	1.98	0.090	0.61	0.20
Ratio C/N	19.44	15.13	1.075	0.44	2.40
N (g/m^2)*	13.94		0.279		1.25

s.e.d.: standard error of the difference (s.e. for pH, OM and N (g/m^2). R^2_{adj}: adjusted R^2; RSE: residual standard error; * estimated according to Hobbs (2006).

In soils, most of the variables analysed showed significant changes, either with livestock species (EC, P and K), or linear increases (EC and nitrates) or decreases (N) with time after the TNC (Table 2). Only the pH remained unchanged and with values almost identical to those before TNC. For all the response variables, except for EC, initial values immediately before the TNC were highly related to those found afterwards, denoting a low spatial variability in this type of soils of low fertility.

EC, K and P had higher values in the soils of goats TNC than in those of sheep TNC. P is mainly excreted via faeces in grazing animals, so its incorporation in the soil might be relatively slow when compared to K, which is mostly excreted in urine (Haynes and Williams, 1993). This may explain why P values in soils after TNC were not very different from values before TNC, while the contrary occurred for K and EC. The ionic form in which K is urinated explains its very high correlation with EC (r=0.91). The much higher values of K and EC in goats than in sheep do not seem to correspond uniquely to their higher intake rate, but probably also to a distinct grazing diet (Ferreira *et al.,* 2013), which may specifically be richer in K. In the case of N, the proportion excreted in urine increases with the N content of the diet. Our simulations resulted in similar proportions of N in faeces and urine. As N in urine is mainly in the form of urea, this could explain the marked increase of nitrate in the soil, possibly responding to urea hydration and posterior ammonia nitrification (Rowell, 1994). The absence of a species effect on soil N agrees with the total N excreted, as recorded in Table 1.

Table 2. Effect of livestock species and time (days) on soil variables after temporary night camps

Variable	Livestock species			Time		RSD
	Goats	Sheep	s.e.	days	s.e.	
pH	4.7		0.20	–		0.27
EC (mS/cm)	0.12	0.07	0.015	+0.0008	0.0003	0.041
P (ppm)	8.44	7.12	0.545	–		
K (ppm)	160.4	105.8	18.81	–		39.21
N (%)	0.52		0.115	-0.001	0.0004	0.05
Nitrates	0		–	+0.30	0.022	4.61

s.e.: standard error (of the difference when goats and sheep values are different). RSD: residual standard deviation of the random effects of the linear mixed model.

IV – Conclusions

Temporary night camps with high livestock density produce noticeable short-term changes in soil nutrients available to plants. Differences between goats and sheep soils may be related to their different diets. Mid and long-term changes in soil and vegetation are currently being monitored in order to quantify the utility of this practice towards pasture improvement.

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